Searches for MSSM Higgs at the Tevatron

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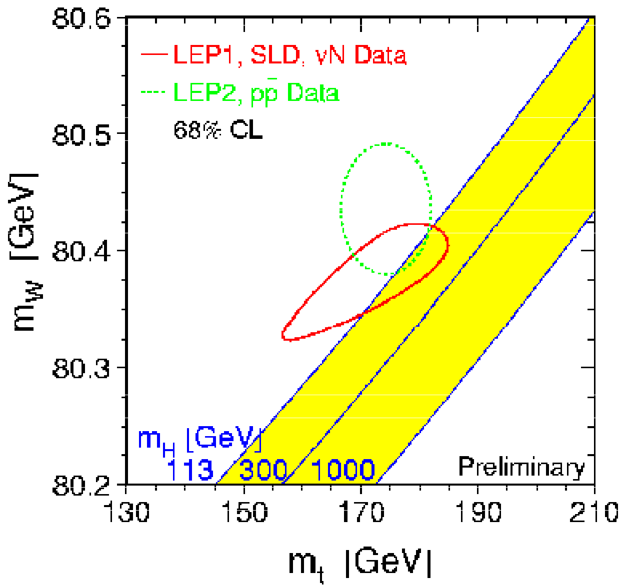
For the CDF and DØ Collaborations

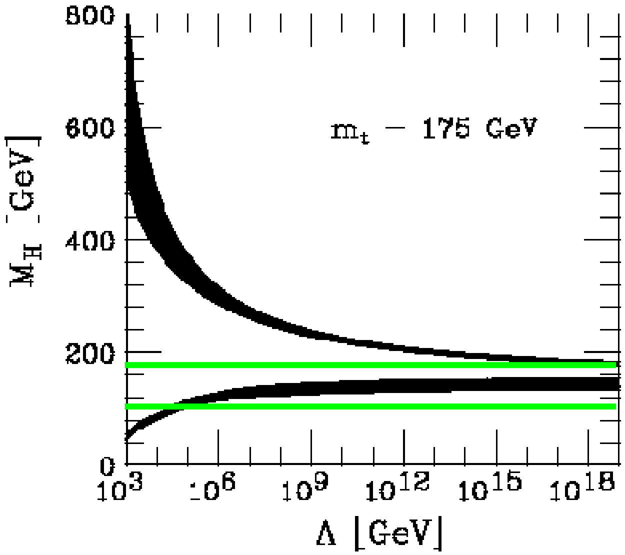
- Motivation
- A/H->$\tau\tau$
  - Run I & Run II (CDF)
- A/Hbb -> bbbb
  - Run 1 Search: CDF
  - Run II:
    - CDF
    - DØ
- Conclusions

Why Higgs? Why MSSM?

- [an] EWSB mechanism in SM
  - Gives mass to particles through H couplings
  - Current data points to light Higgs
    M_{Higgs} < 170 GeV @ 95%, Osaka'00
  - Higgs has not been definitively observed
    LEP2: > 114 GeV 95% CL exclusion



- [a] solution to hierarchy problem
  - m_H^2 receives corrections ~ m_{Planck}^2
  - Needs fine- tuned parameters for m_H~100 GeV
  - Supersymmetry: symmetry between fermions, bosons - > cancellations occur naturally
  - Two Higgs doublets are needed

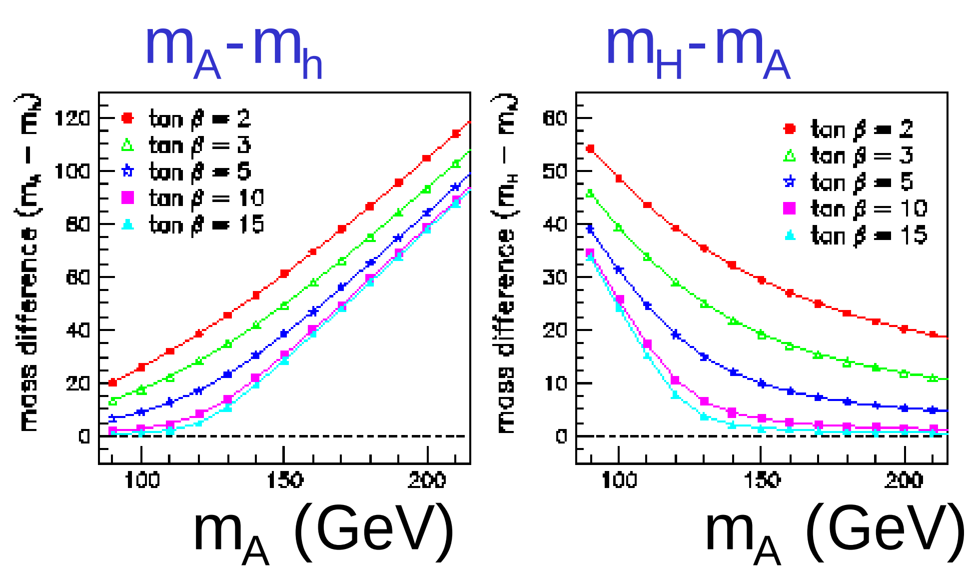


MSSM Higgs

- **In the MSSM scenario:**
  - **Two Higgs doublets lead to 5 Higgs particles:**
    - **Two neutral CP- even: h,H**
    - **One neutral CP- odd: A**
    - **Two charged: H^+ ,H^-**
  - **Masses governed by two parameters, for ex:**

$$\{m_A, \tan\beta\}$$

  - **Tree level mass relations:**
    - **M(h)<M(Z)<M(H)**
    - **M(A) <M(H)**
    - **$M(H^+)$<M(W)**
  - **$M(h^o)$<~130 GeV after radiative corrections** (top,stop etc.)



- High tanb:
  - A nearly degenerate with
    - h (m_A<~130 GeV)
    - or H (m_A>~130 GeV)

MSSM Higgs production @ Tevatron

- H/h/A can have SM-like x-sections at small tan β

  For processes such as HW and HZ

- Some production processes such as:

  gg->A/H

  gg,qq-> Hbb/hbb/Abb

  can have

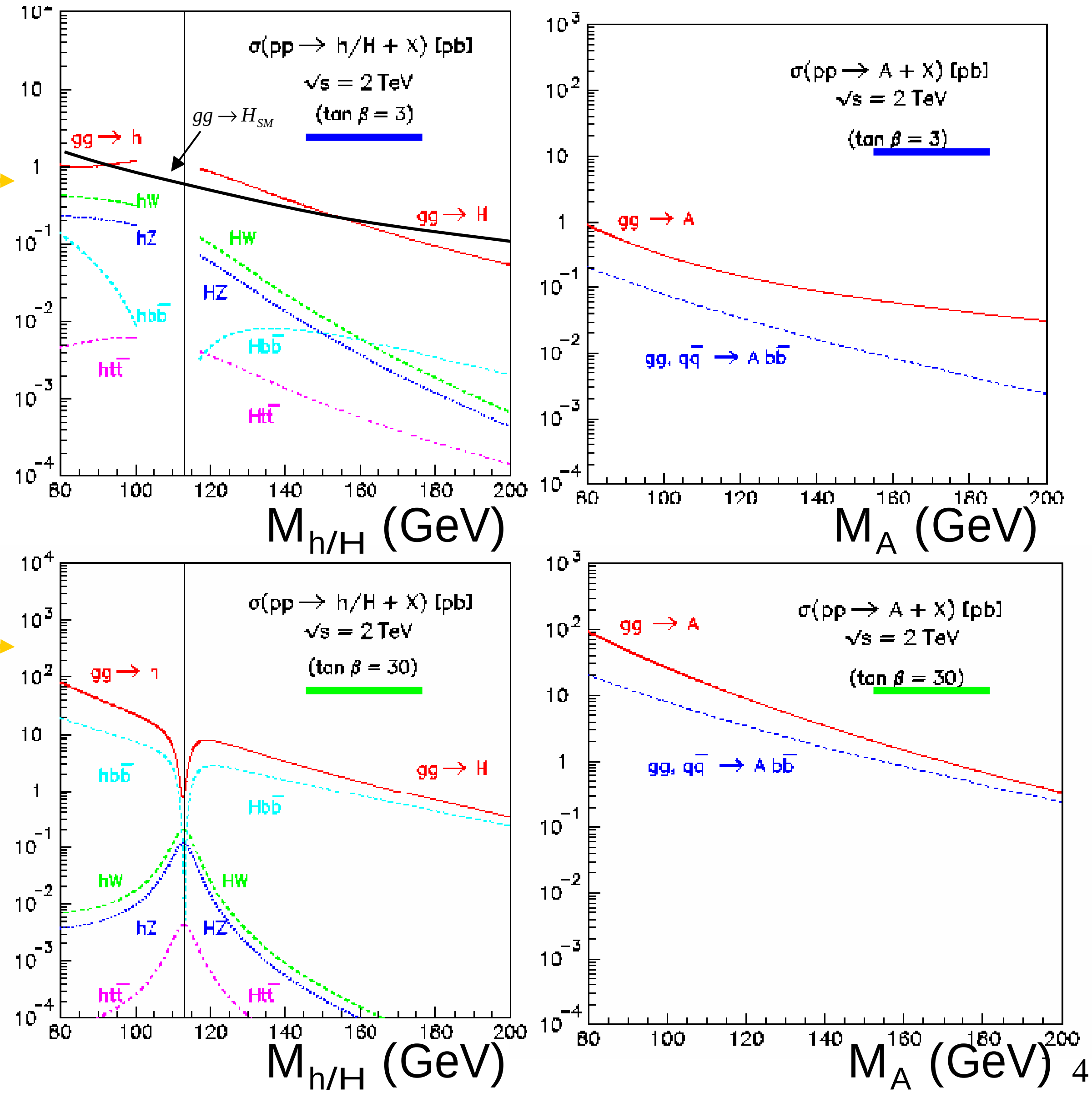
  large x-sections at

  large tan β !!!

$$\sigma(p\bar{p} \to \varphi) = (g^{h,A,H})^2 \sigma(p\bar{p} \to H_{SM})$$

$$\sigma(p\bar{p} \to b\bar{b}\varphi) = (g^{h,A,H})^2 \sigma(p\bar{p} \to b\bar{b}H_{SM})$$

g ~ 1/cosβ ~ tanβ **φ = h,H,A**



MSSM Higgs Branching Ratios

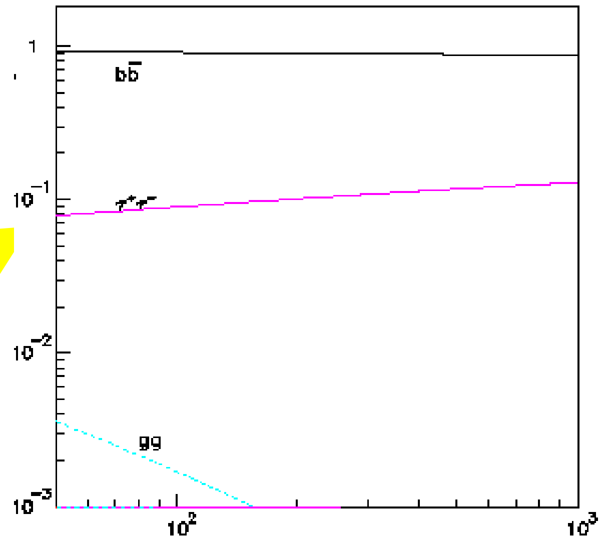
In the same high tanβ region, BR(->fermions) stays high even at large mass.

For all practical purposes:

$\varphi \rightarrow$ bb ~ 90%

$\varphi \rightarrow \tau\tau$ ~ 10%

$\tan\beta = 50$

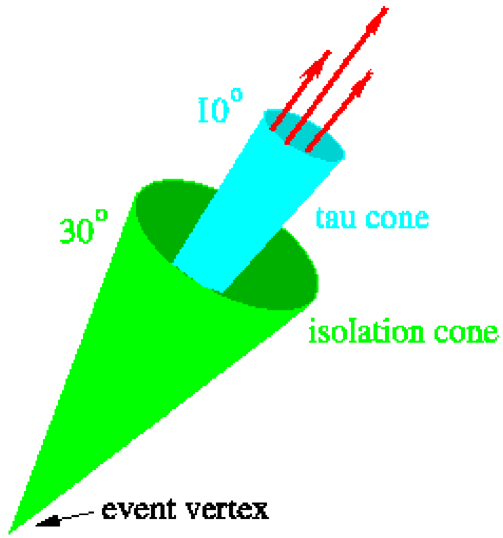


m_A (GeV)

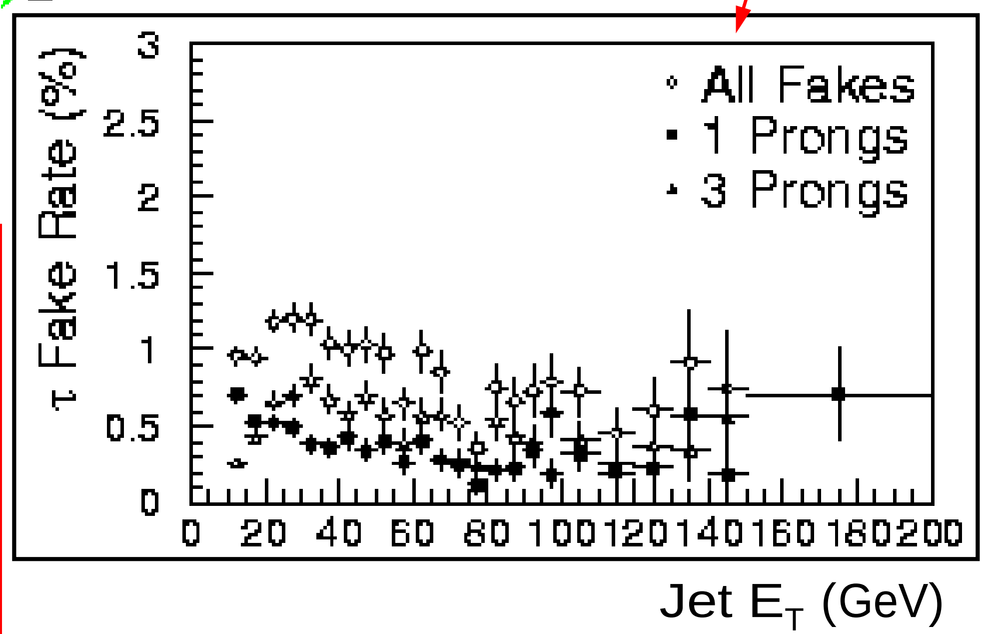
- Searches for Higgs in high tanb region at Tevatron:
  - gg->A/h->$\tau\tau$
  - gg,qq->A/hbb->bbbb

A/H- >$\tau\tau$:
Tau ID in Run I (CDF)

- **Tau Properties:**
  - **Collimated decay products**
    - **Opening angle:**
      $\theta < m_\tau/E_T(\tau)$ <~ 0.2 rad ~ 10°
  - **Low multiplicity tracks, photons in 10°**
  - **Visible energy reconstructs low mass**
- **Cuts:**
  - **Jet with high visible E_T containing high p_T track**
  - **Isolated in 10°- 30° annulus**
  - **Low track, photon multiplicity in 10° cone**
  - **m_τ<1.8 GeV**
  - **|Q|=1**



Achieved fake rates ~1.2- 0.7% for jet E_T 20- 200 GeV



Photons detected in wire chambers at shower-max in the EM Calorimeter: 2D info, $\sigma(x)$,$\sigma(z)$~2cm

A/H->ττ: Ditau Mass Reconstruction (CDF)

$$\not{E}_x^{\,meas} = \not{E}_x^{\,\tau 1} + \not{E}_x^{\,\tau 2}$$

$$\not{E}_y^{\,meas} = \not{E}_y^{\,\tau 1} + \not{E}_y^{\,\tau 2}$$

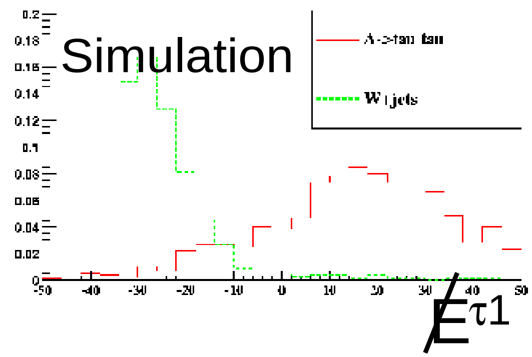
Full mass of the ditau system may be reconstructed if:

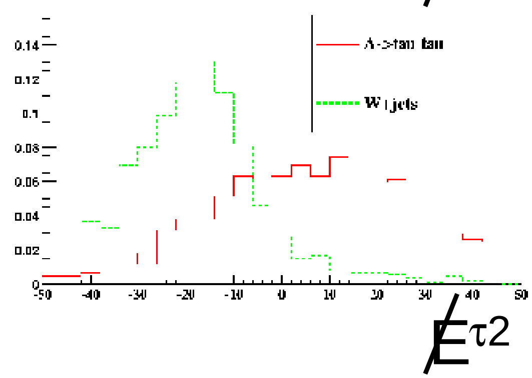
1. Assume ν's in same direction as visible decay products
2. Taus are not back-to-back in azimuthal ->require $\Delta\phi<160°$

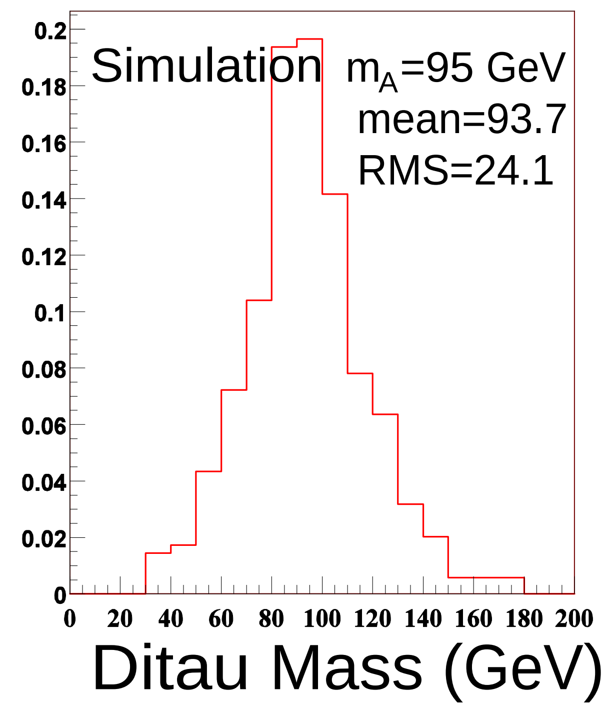
Require $E_\nu^{1,2}>0 \rightarrow$

Lose 50% Higgs signal,

Reject 97% W+jets







A/H->$\tau\tau$ (CDF)

- Trigger
  - No τ trigger in Run I $\rightarrow$ use p_T>18 GeV lepton trigger->

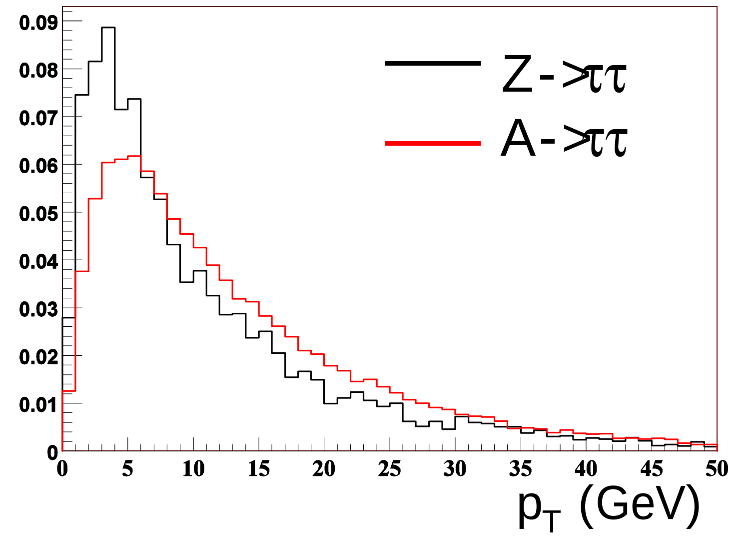
One leptonic τ
One hadronic τ

- Backgrounds
  - Z $\rightarrow$ $\tau\tau$ (irred.), QCD, Z $\rightarrow$ ee, W+jets: non-irred. backgrounds rejected through tau ID cuts and mass reconstruction

Use m_A=95 GeV, tanβ=40 as benchmark:
σ(A/H $\rightarrow$ $\tau\tau$)=8.7pb

Z $\rightarrow$ $\tau\tau$ irred. backgnd, but:

- Branching Ratio:
  - Z$\rightarrow\tau\tau$: 3.7%
  - A/H $\rightarrow$ $\tau\tau$: 9%
- P_T Distributions
  - Stiffer A/H p_T distributions than Z p_T distributions:
  - $\Delta\phi$<160° cut ~ p_T>15 GeV cut $\rightarrow$ 30% more efficient for Higgs than Z



σ(A/H) falls fast! Drops by factor of 4 from 95 –120 GeV, 1 RMS ($m_{\tau\tau}$) ~24 GeV -> Need as high a rate as possible! ->

Taus in Run II (CDF,DØ)

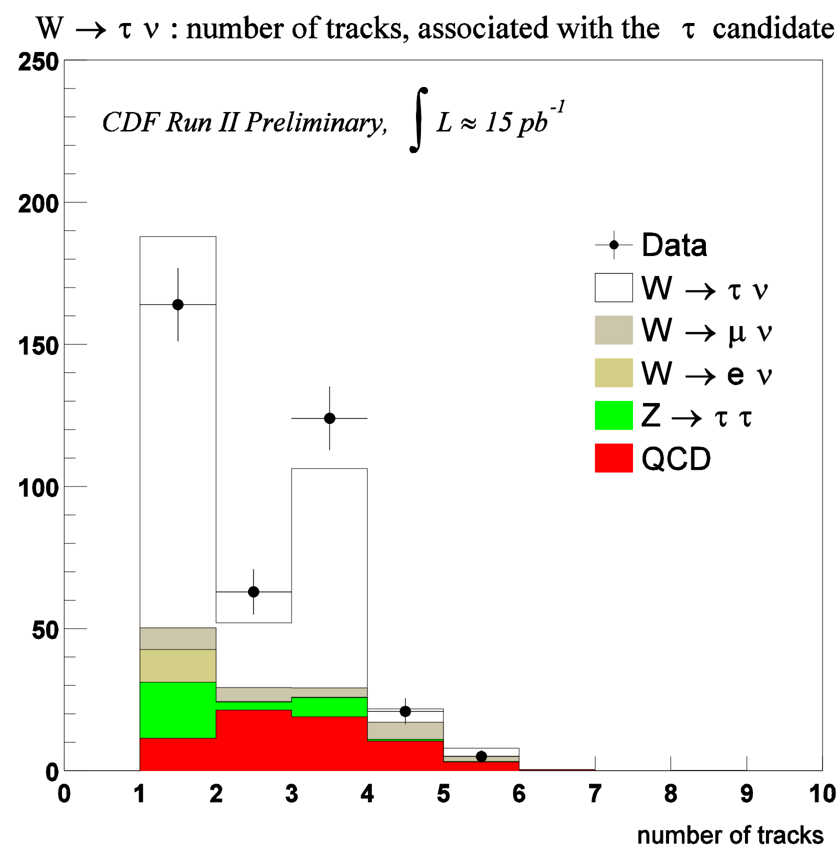
Triggers designed for τ physics will greatly increase the acceptance for this search:

- **Lower p_T thresholds**
- **All- hadronic modes open up (~1/2 of branching ratio)**

Tau Triggers in Run II:

- **Lepton + track triggers (DØ, CDF)**
- **τ+MET Trigger (DØ,CDF)**
- **2 hadronic τ's**
  - **Calorimeter- based (CDF)**
  - **Track- based (DØ)**

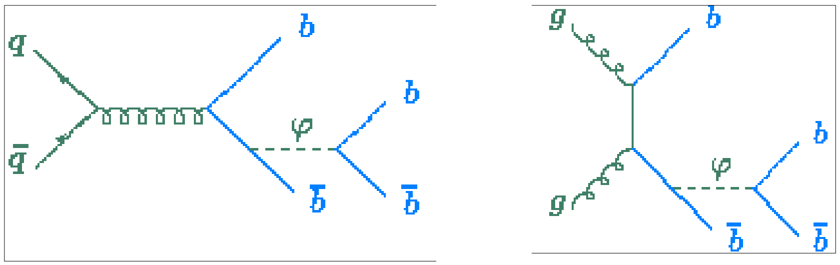
Run I A/H->$\tau\tau$ search sill work in progress, Run II analysis in the works as well



CDF already sees W$\rightarrow\tau\nu$ events from new τ+MET trigger!

pp -> bbA/h/H -> bbbb: Run I (CDF)

φ = **h,H,A**



Event selection:

> 4- jets + ΣE_T>125 GeV trigger

> ≥ 3 b-tag (displaced vertex)

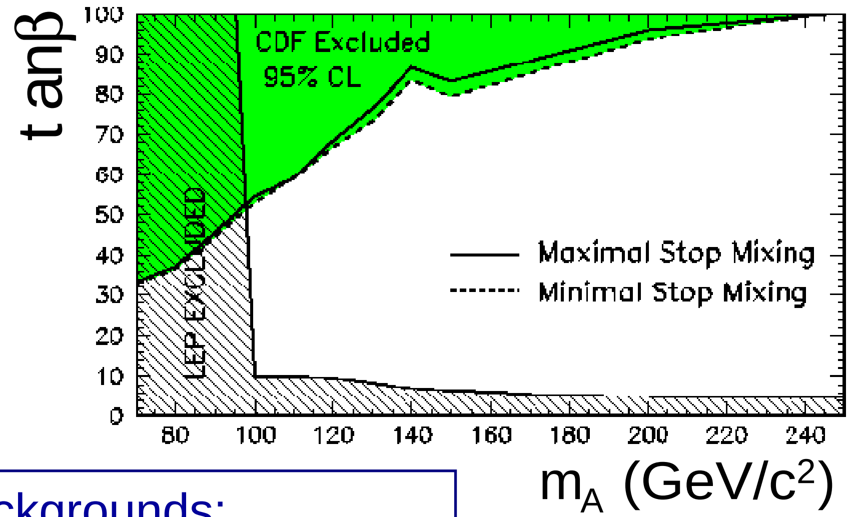
> $\Delta\phi_{bb}$ > 1.9

> m_φ dependent cuts optimized for max. expected signif.:

> > E_T cuts on jets

> > mass window 1-3σ

BR x Accept ~ 0.2 – 0.6% ($70<m_\varphi<300$ GeV)

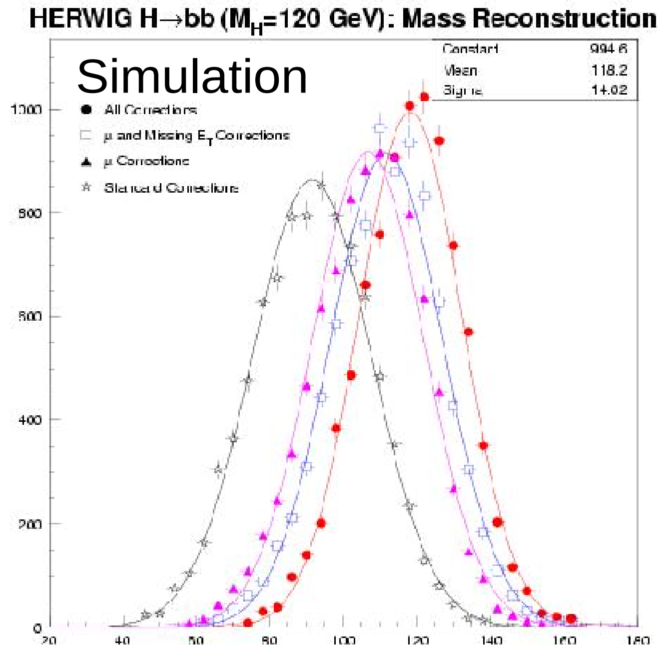


Backgrounds:

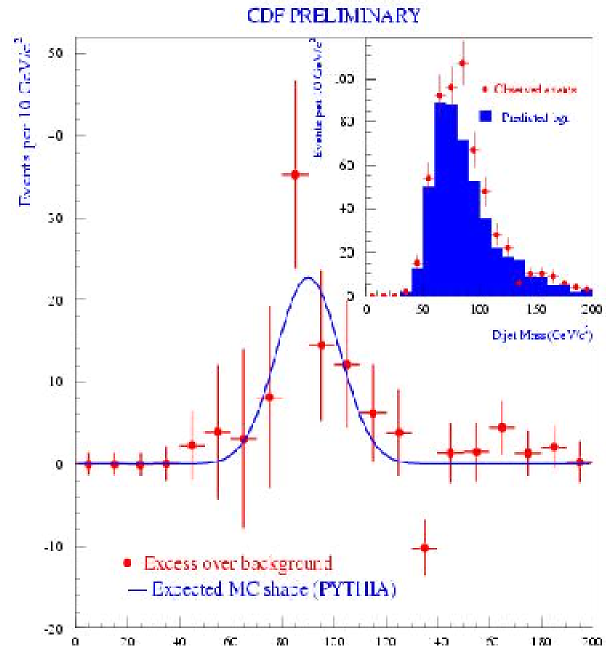
QCD, Z/W+jets, tt

- For m_φ = 70 GeV hypothesis, observe 5 events, expect 4.6 ± 1.4
- Only these 5 events appear in higher mass windows
- No excess above predicted is observed

Tools for pp -> A/h/Hbb -> bbbb: Run II (CDF)



Dijet Invariant Mass (GeV)



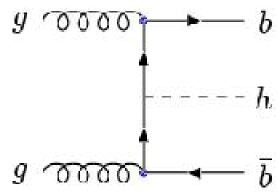
Dijet Invariant Mass (GeV)

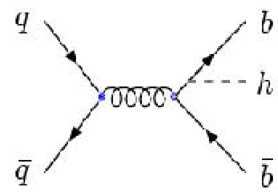
•Z->bb studies -> improved resolution
 - correcting for μ, $\not E_T$, jet charged fraction

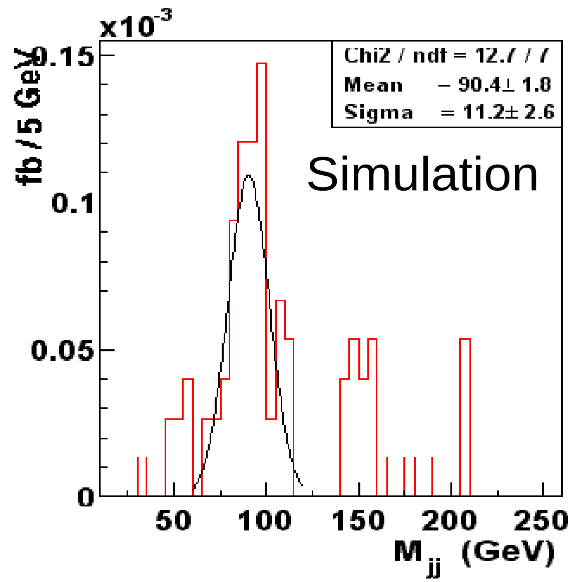
•Studies of QCD jets
 - 30% improvement in jet res.
 - uses tracking, shower-max detectors and calorimetry

- B-tagging:
  - 3D silicon
  - $|\eta| < 2$
- Improved lepton acceptance
- New specific triggers to recover acceptance (displaced track trigger, multijet)

Tools for pp -> A/h/Hbb -> bbbb: Run II (DØ)





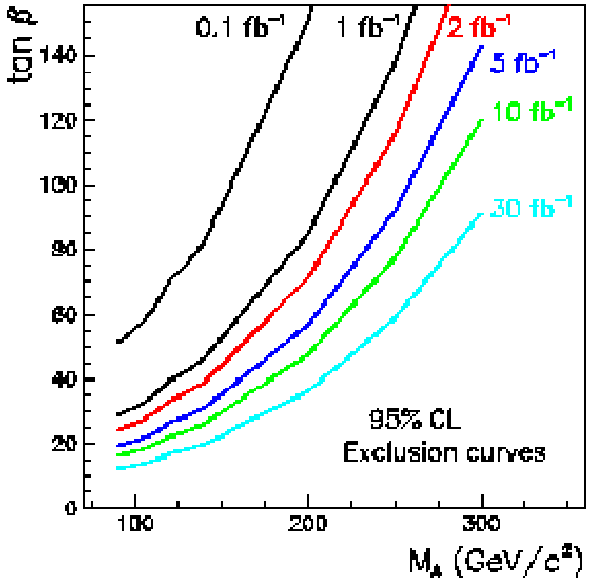


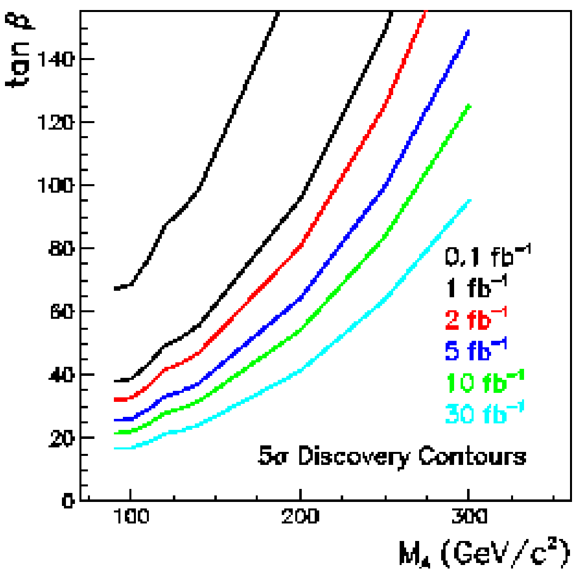
- **Obtain fractional resolution σ/M ~ 12%**
  - **No jet calibration applied**
- **Consider all jet permutations for mass reconstruction**
- **Predicted rates normalized to SM prediction (3.7 fb)**
- **Started recently to look at $gb \rightarrow bh$ channel which has an order of magnitude larger cross section**

- **Multijet trigger: 4 jets, E_T>15 GeV, $|\eta|$<2**
  - **Leading jets: m_φ dependent cuts**
    - **m_φ=120: E_T^1>55 GeV, E_T^2>40 GeV**
  - **ΣE_T of jets 3 and 4 > 30 GeV**
  - **At least 3 b tags**
    - **plot all mass combinations, look in mass window**

Projected Reach in Run II (CDF, DØ)

- Both experiments study expected Run II sensitivity from bbbb analysis
  - similar results





$2fb^{-1}$:

->160 GeV (tanβ=40) 95% CL

->115 GeV (tanβ=40) 5σ discovery

Conclusions

- A/H->$\tau\tau$:
  - **Run I results to be completed soon**
  - **First glimpse of Run II data also on the way**
- A/Hbb->bbbb:
  - **Run I result excludes - > 115 GeV at tanβ=60**
  - **Run II with both experiments:**
    - **Set to exclude (discover) significant region of MSSM parameter space**
    - **Optimistic about improvements from**
      - **Triggers**
      - **Jet resolution**
      - **b- tagging**